Measuring the Υ Nuclear Modification Factor at STAR

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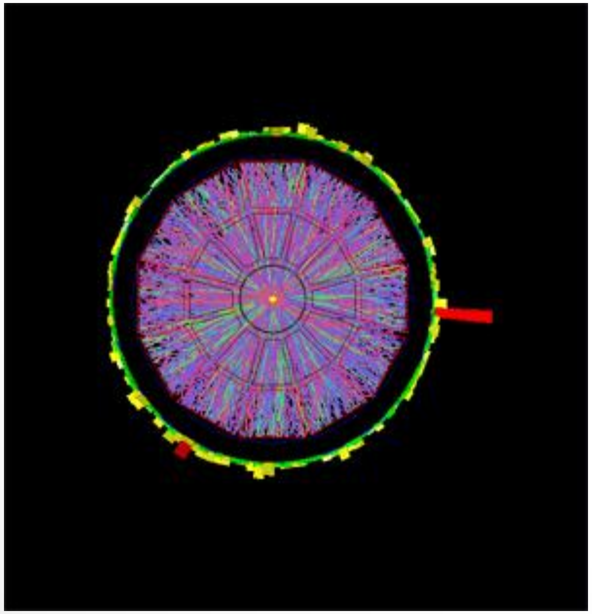
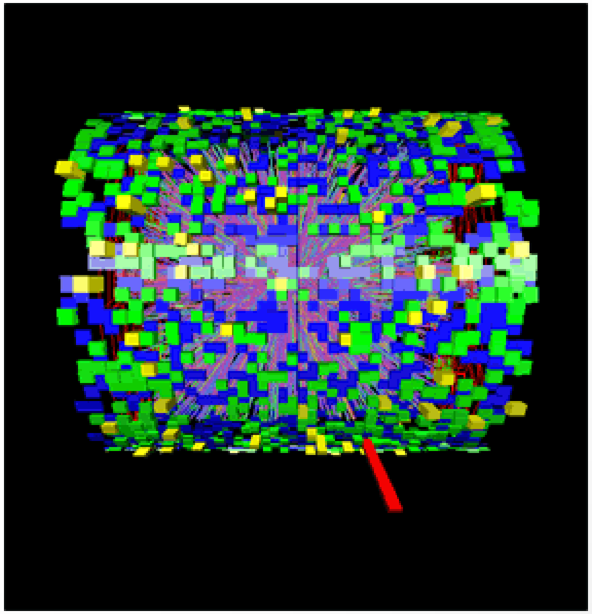
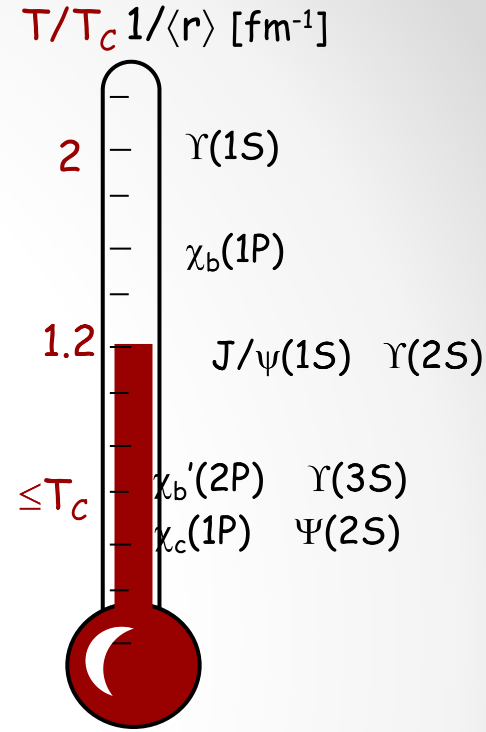
for the STAR Collaboration



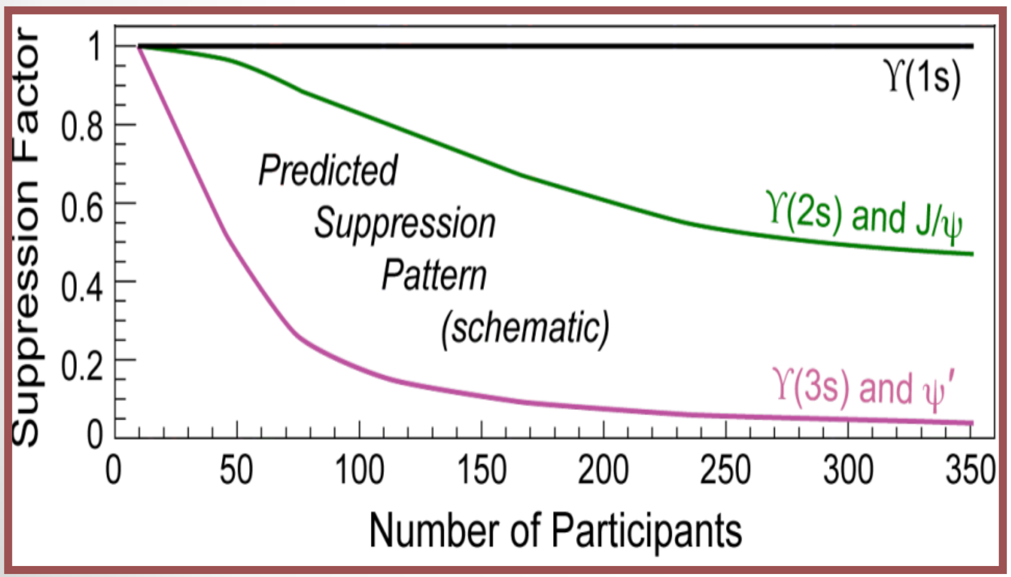


Motivations

Sequential suppression of Quarkonium mesons acts as a QGP thermometer.



] A. Mocsy and P.Petreczky, PRL 99, 211602 (2007)



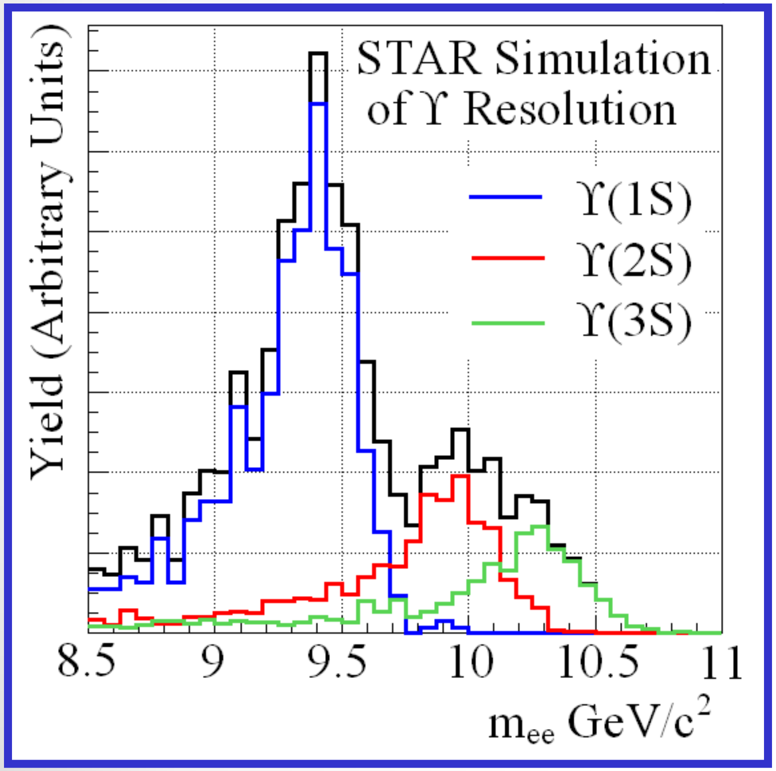
Expectation at 200 GeV

ϒ(1S) does not melt

ϒ(2S) is likely to melt

ϒ(3S) will melt

Υ at STAR



- Decay channel: $\Upsilon \rightarrow e^+e^-$

Pros

- Small background at M~10 GeV/c^2
- Co-mover absorption is small at 200 GeV
- Recombination negligible at 200 GeV
- Large Acceptance
- Fast Trigger

Cons

- Low rate of 10^{-9} per minbias pp interaction
- Good resolution needed to separate 3 S-states

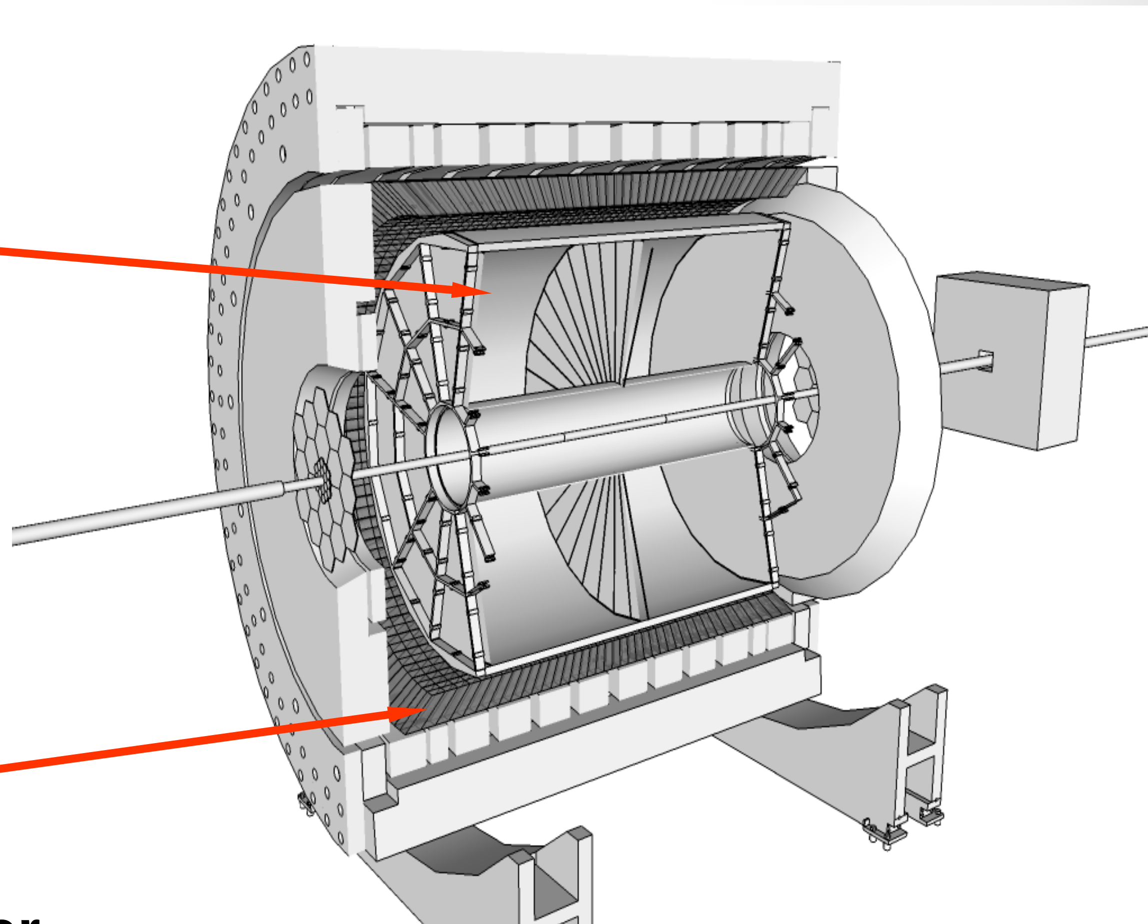
ϒ at STAR

TPC

$|\eta| < 1, 0 < \phi < 2\pi$

Tracking → momentum

dE/dx → electron ID



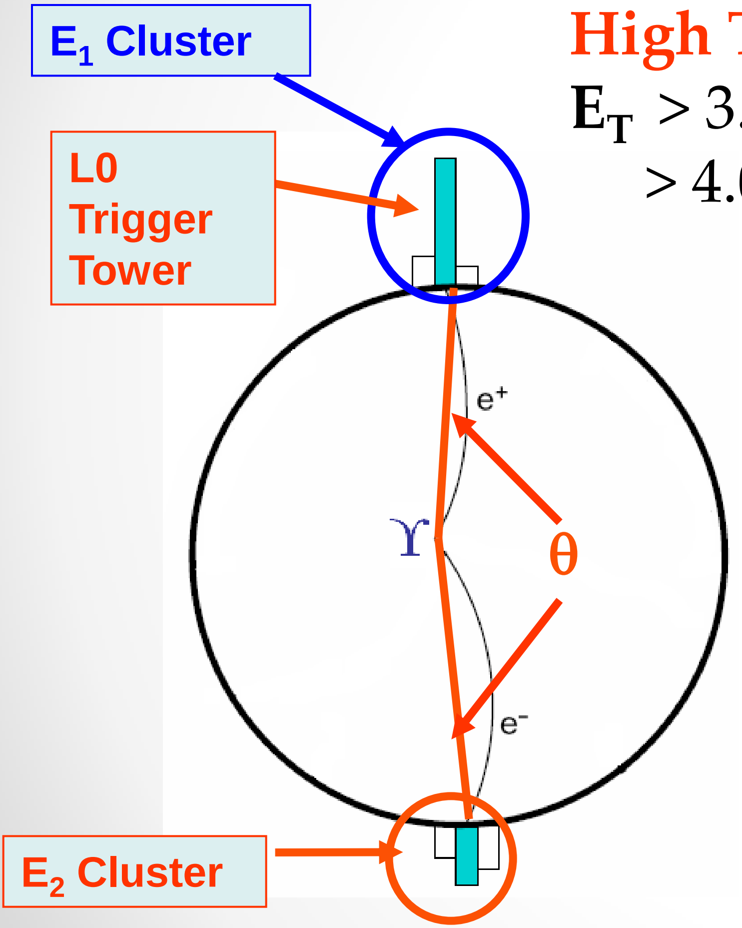
BEMC

$|\eta| < 1, 0 < \phi < 2\pi$

E/p → electron ID

High-energy tower trigger

Trigger and Analysis



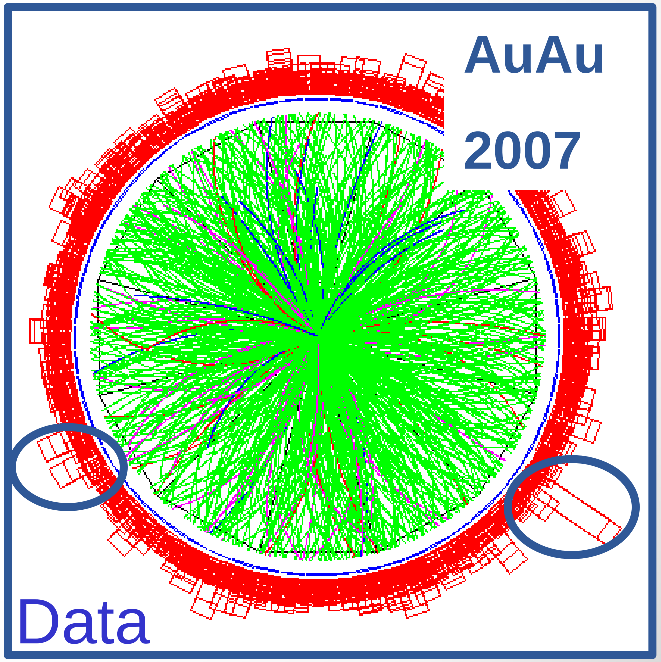
High Tower

E_T > 3.5 GeV (pp)

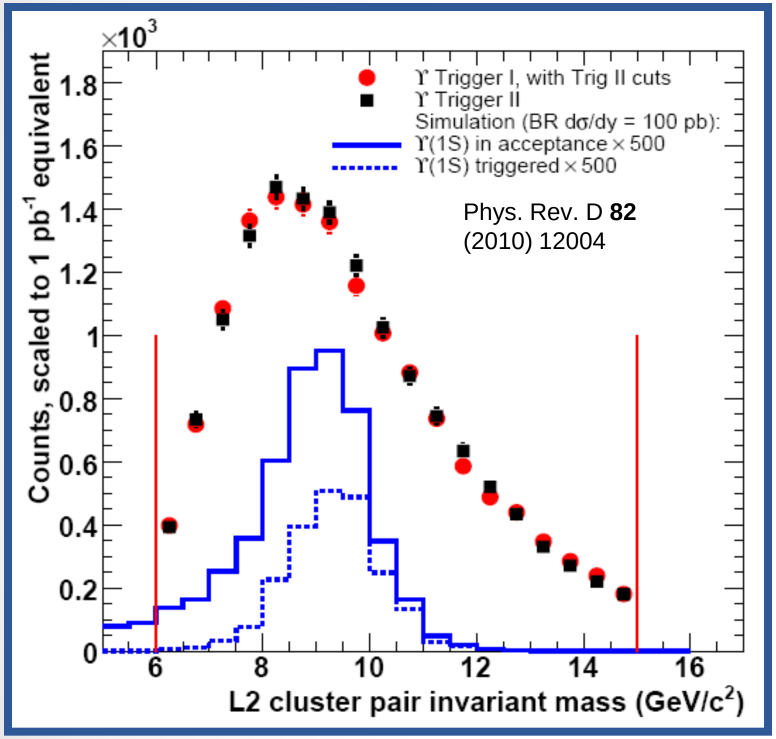
> 4.0 GeV (AuAu)

L2 Parameters
(pp only)
E$_1$ Cluster,
E$_2$ Cluster,
Cos(θ),
Invariant Mass

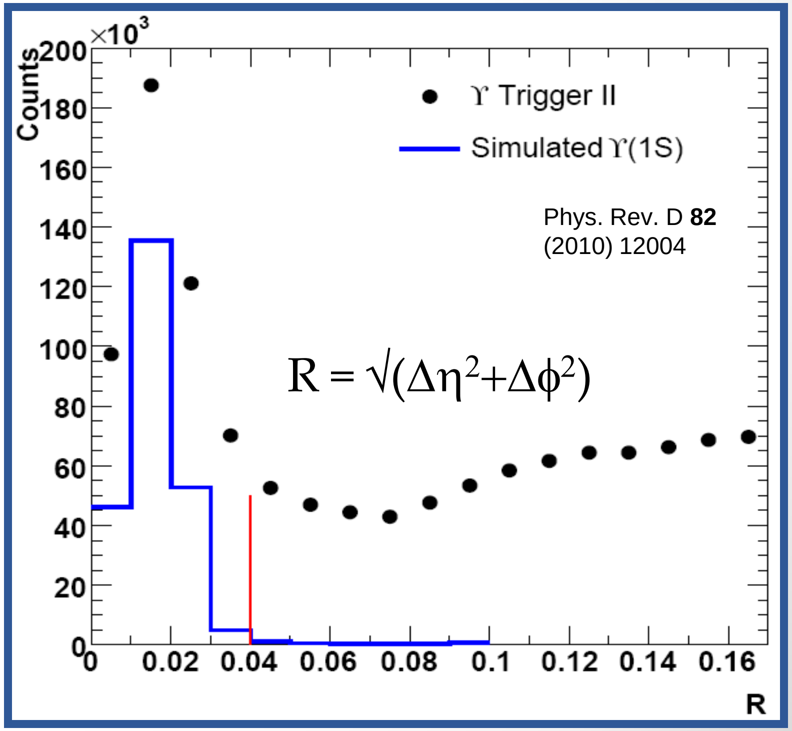
Rejection
~10^5 in pp
Can sample
full luminosity



Analysis Techniques

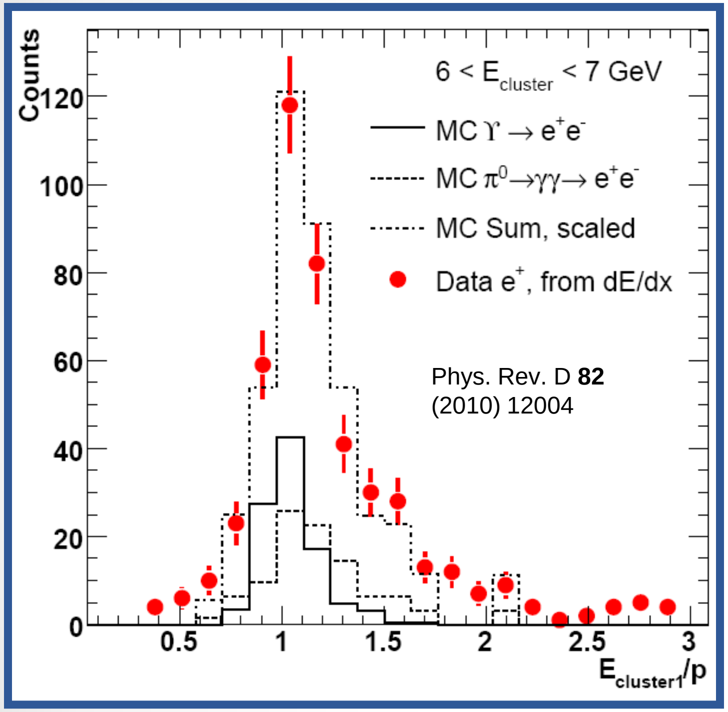


Triggered candidates exceed number of ϒ by a factor of ~700 (p+p)

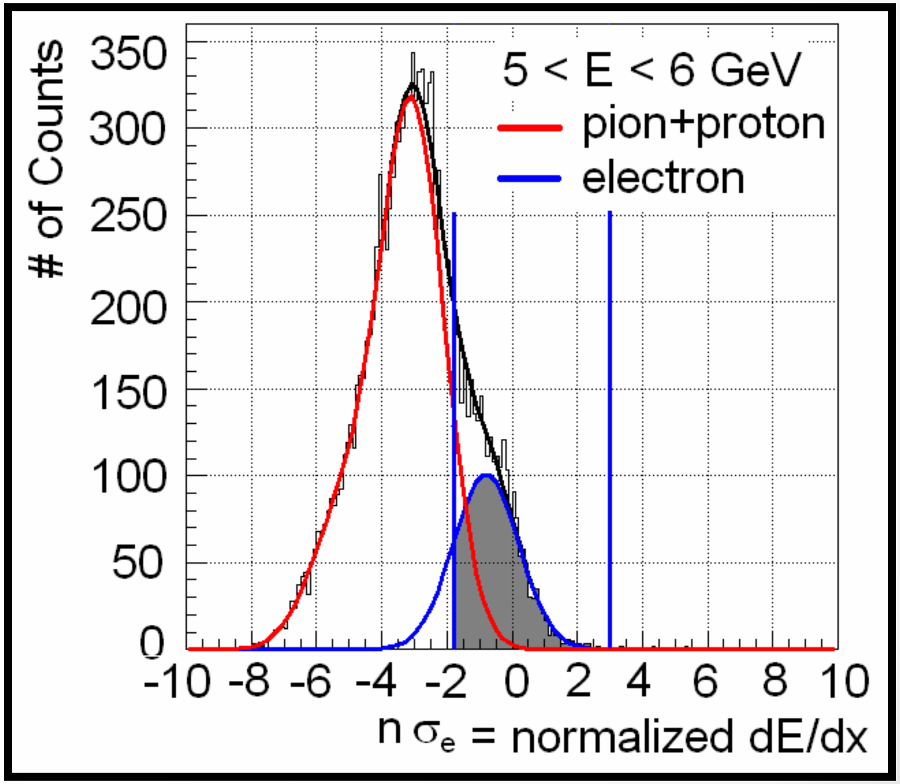


TPC tracks that extrapolate to R=0.04 in η–ϕ to trigger clusters are "matched"

Electron PID



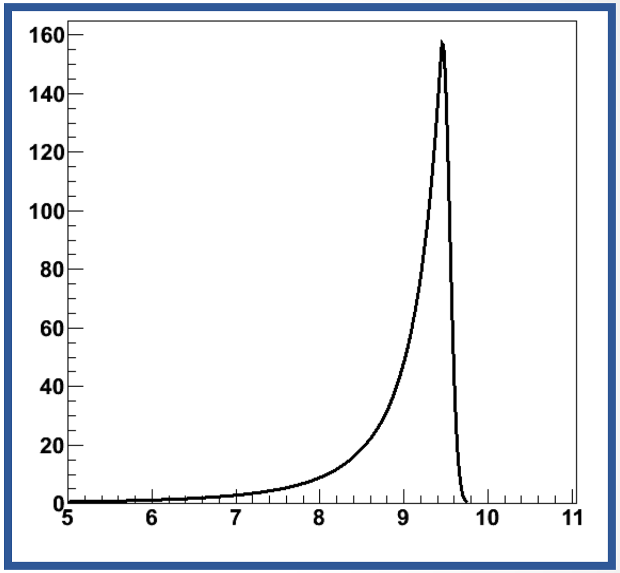
E/p and dE/dx of matched tracks are used to select e^+ and e^- tracks



Electron purity is ~98% in p+p for single electron case

Analysis Techniques

Line shape is a crystal function parameterized by a comparison with simulation



$$f(x;\alpha,n,\bar{x},\sigma)=\begin{cases}\exp\left(-\frac{(x-\bar{x})^2}{2\sigma^2}\right), & for\ \frac{x-\bar{x}}{\sigma}>-\alpha\\ A\left(B-\frac{x-\bar{x}}{\sigma}\right)^{-n}, & for\ \frac{x-\bar{x}}{\sigma}\leq-\alpha\end{cases}$$

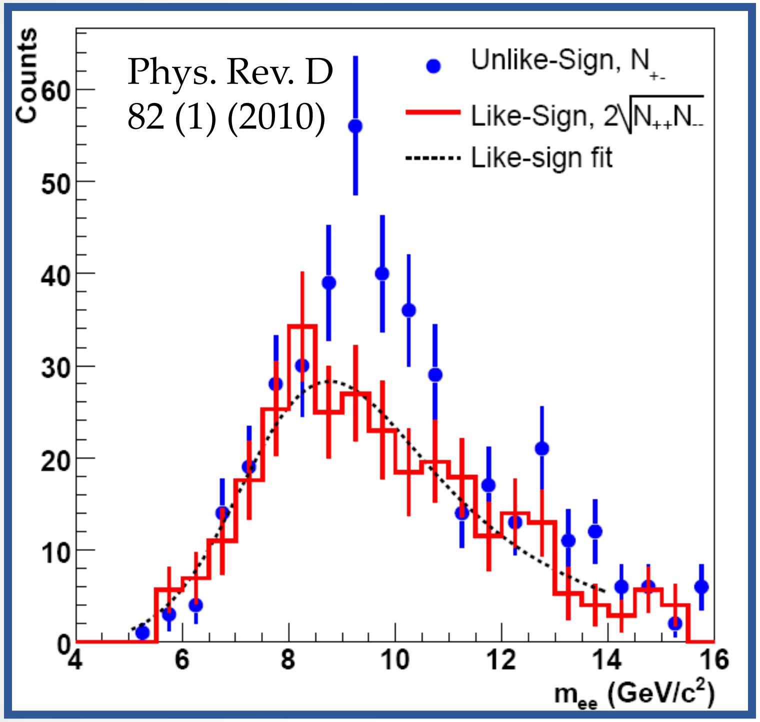
$$B=\frac{n}{|\alpha|}-|\alpha| \qquad A=\left(\frac{n}{|\alpha|}\right)^n\exp\left(-\frac{|\alpha|^2}{2}\right)$$

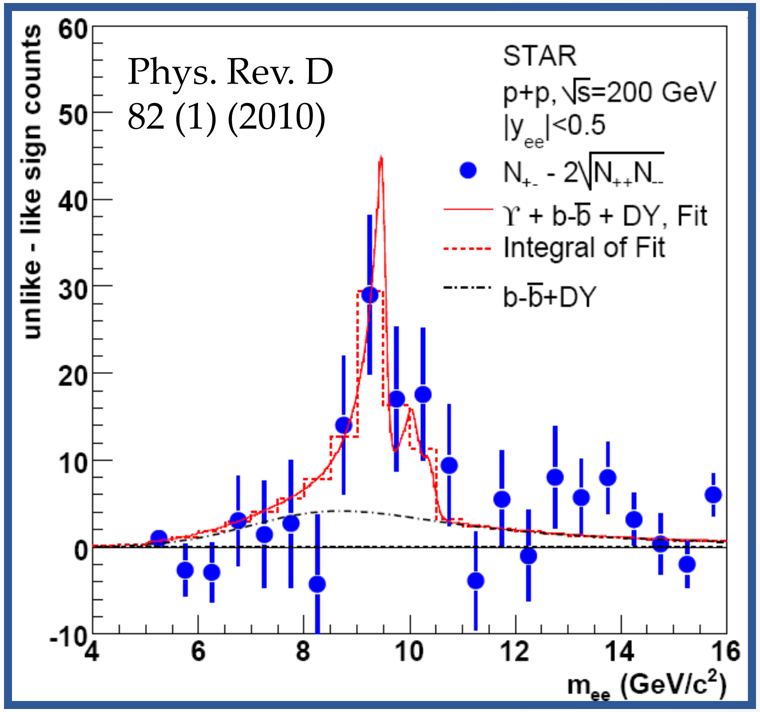
Parameterization of non-Combinatoric background:

$$\text{Drell-Yan}+b\bar{b}=\frac{A}{\left(1+\frac{m}{m_0}\right)^n}$$

n = 4.59, m_0 = 2.7

Υ(1S+2S+3S) cross-section p+p 200 GeV



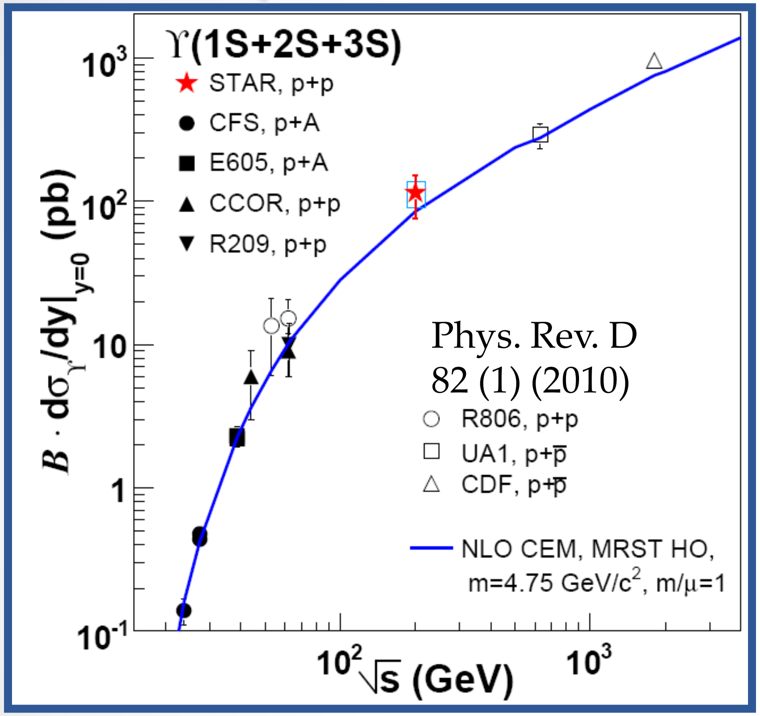


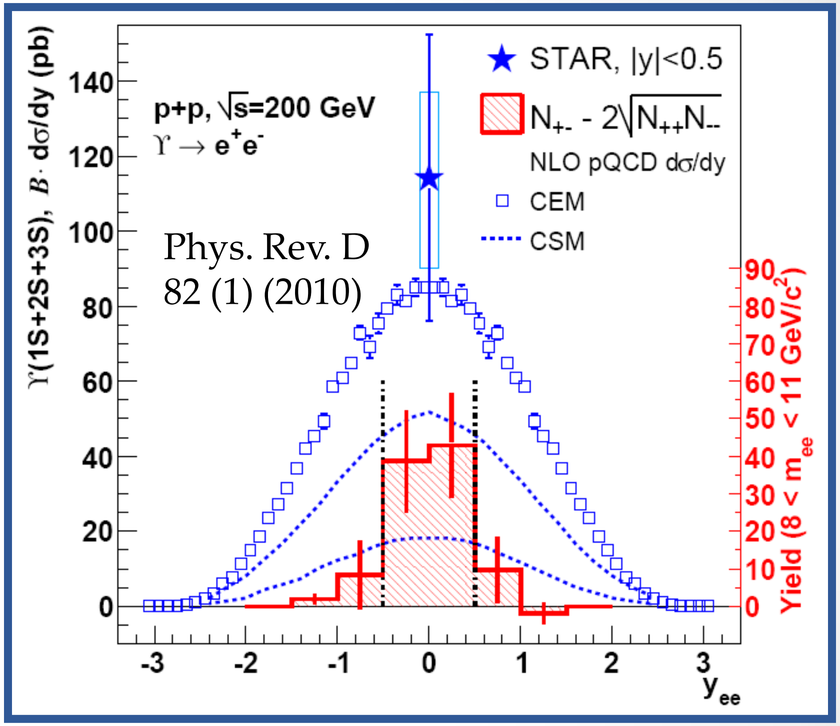
$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 114 \pm 38 \; ^{+23}_{-24} \text{ pb}$$

$\mathcal{L}$ = 7.9 ± 0.6 pb^{-1}

N_{Υ}(total)= 67±22(stat.)

Υ(1S+2S+3S) cross-section

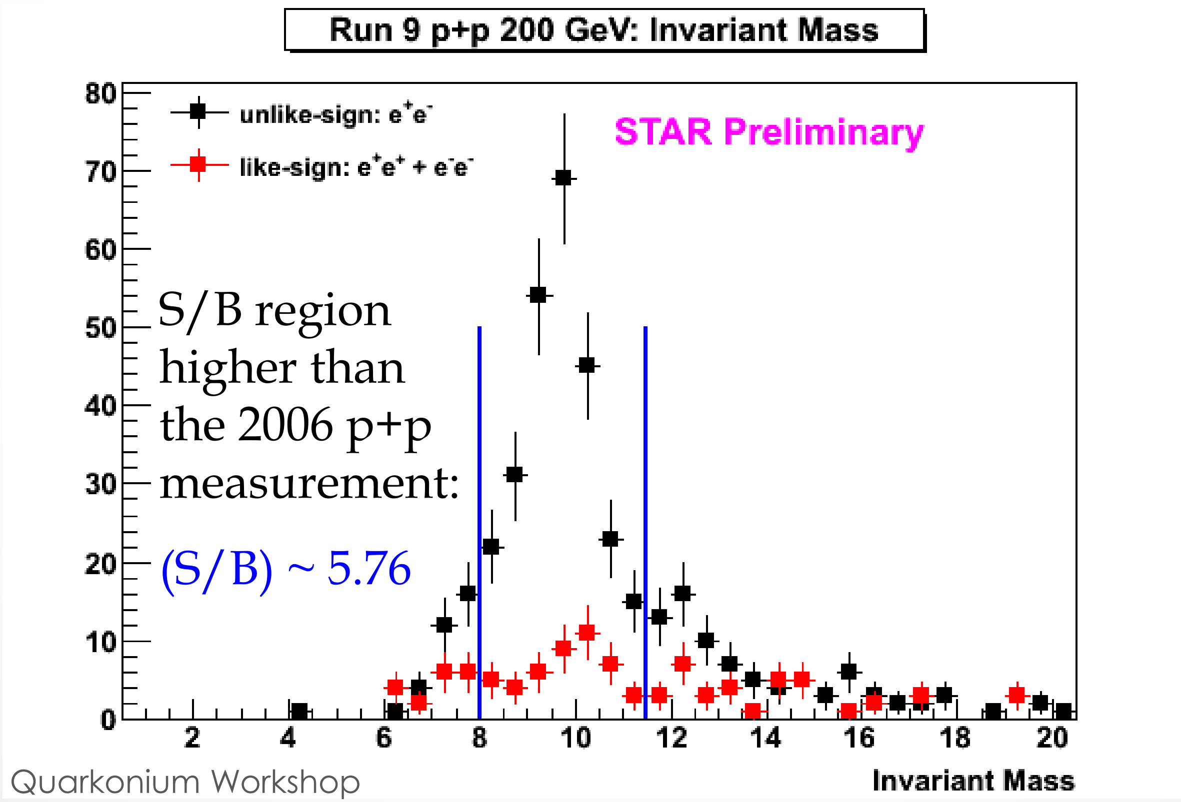




STAR 2006 √s=200 GeV p+p
Υ+Υ′+Υ″→e⁺e⁻ cross section consistent
with pQCD and world data trend

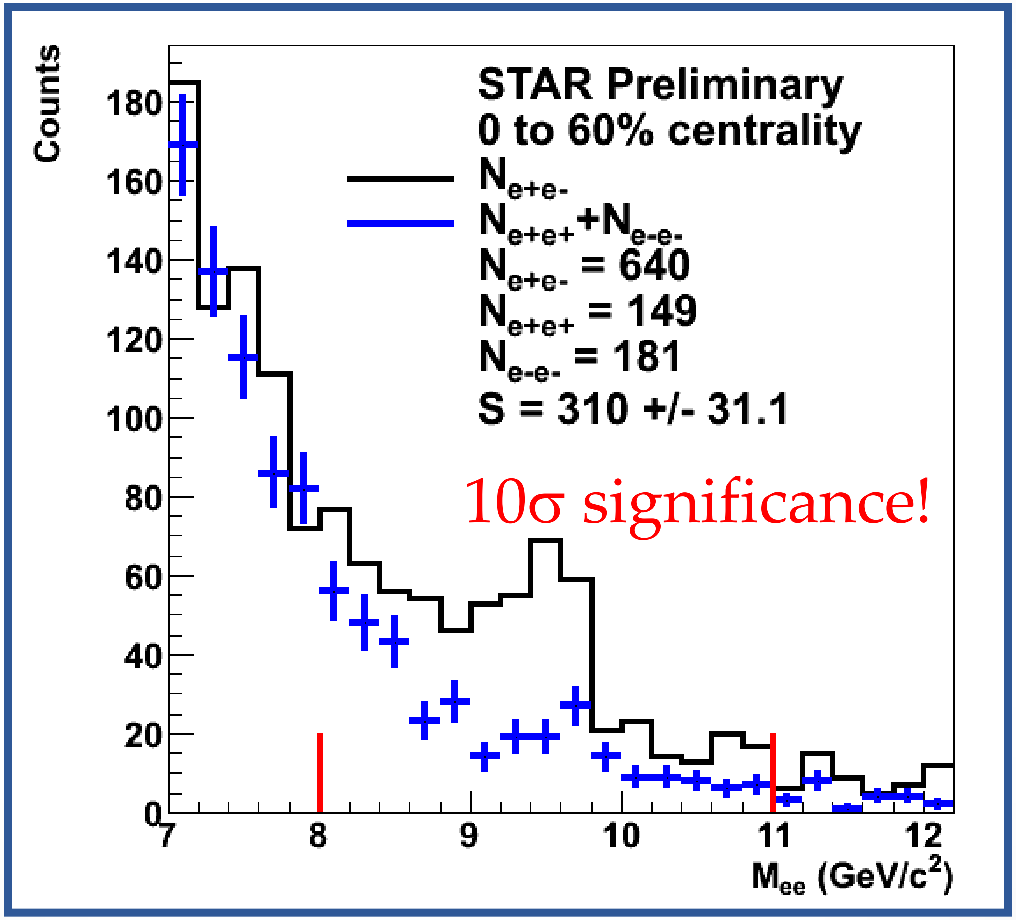
Υ(1S+2S+3S) cross-section

New cross-section measurement with ~x3 the statistics to be available shortly



ϒ Yield 0-60% Centrality Au+Au

Run 10 Data
# of minimum Bias events= 4.62×10^9
Triggers= 50M

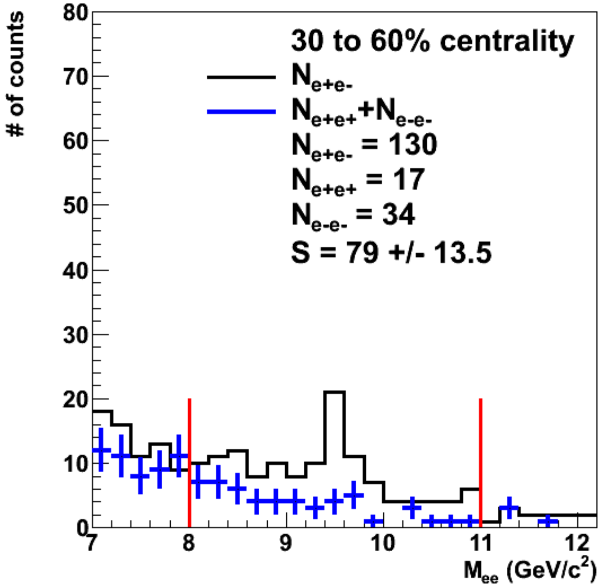


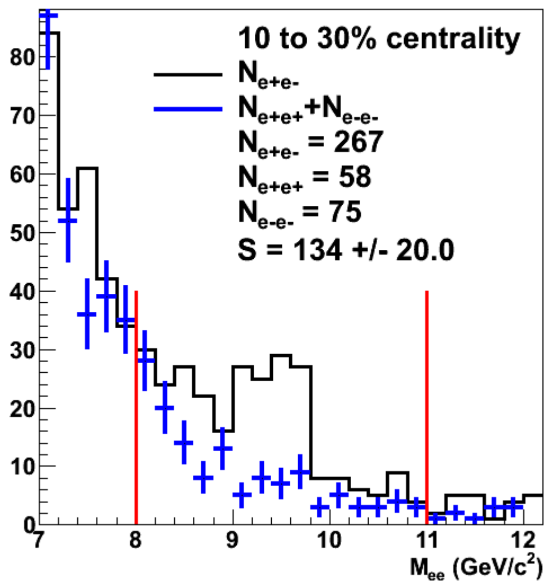
Raw yield of $\Upsilon\to e^+e^-$ with $|y|<0.5$ = 196.6 ±35.8

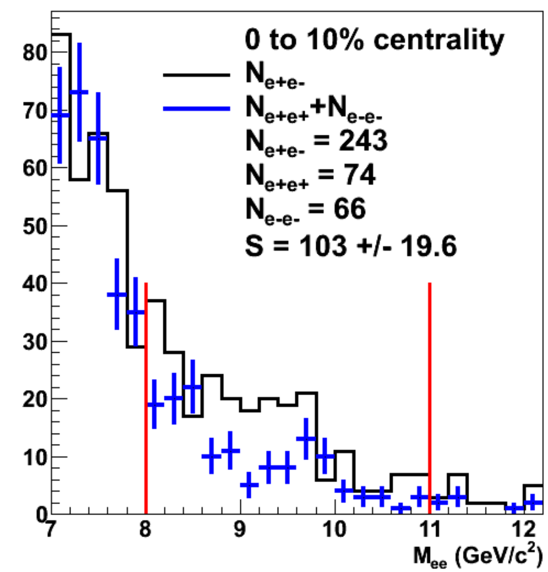
- $= N_{+-} - N_{--} - N_{++} - \int DY + b\bar{b}$

ϒ Yield by Centrality

Peripheral **Central**

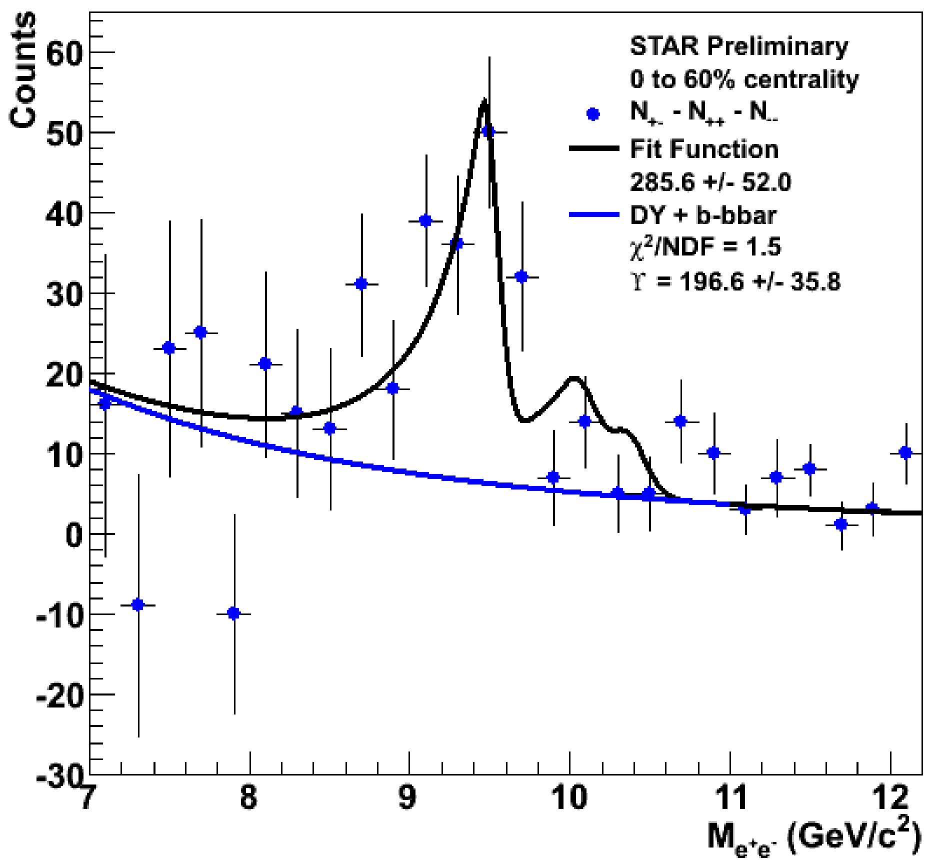






5.9σ 6.7σ 5.3σ

Extracting ϒ(1S+2S+3S) Yield



Current resolution does not allow for a separation of the 2S+3S states

Large theoretical uncertainty in the Drell-Yan and $b\bar{b}$ yield

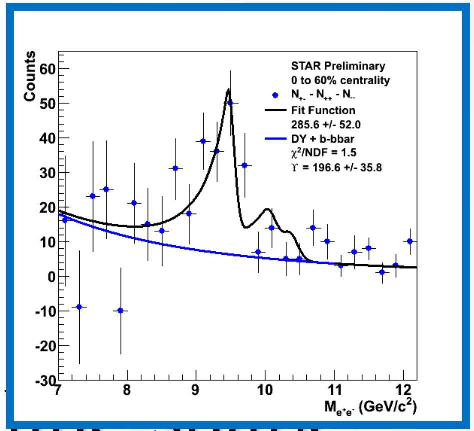
How do we extract a yield unbiased by our initial suppression assumptions?

$$\text{Drell-Yan}+b\bar{b} = \frac{A}{\left(1+\frac{m}{m_0}\right)^n}$$

n = 4.59, m_0 = 2.7

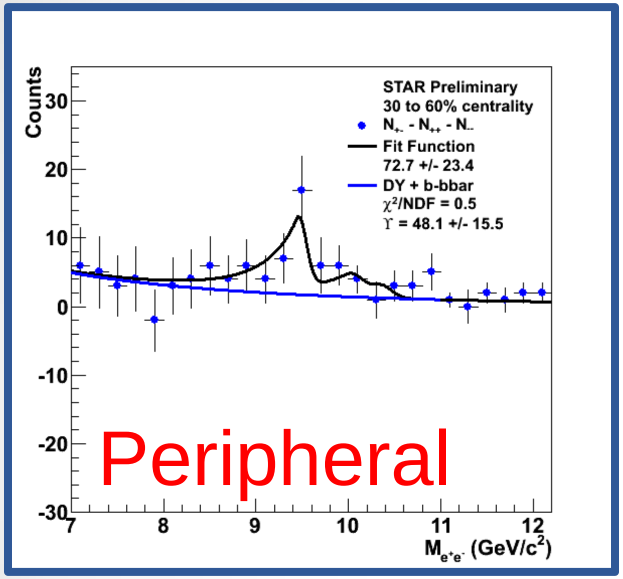
Extracting ϒ(1S+2S+3S) Yield

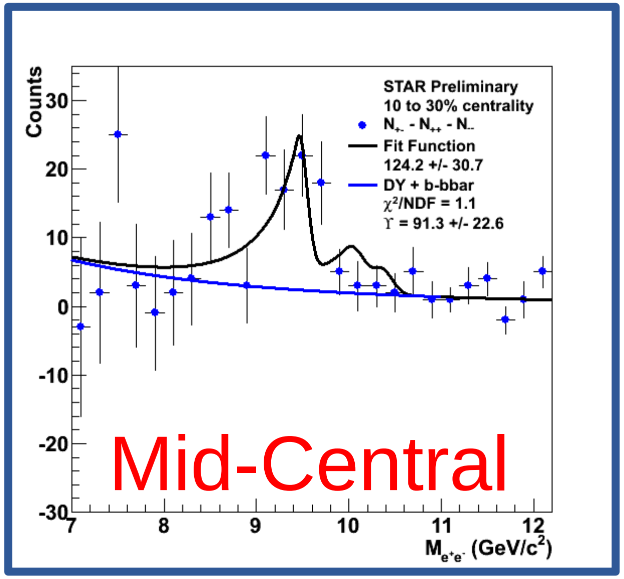
- Fit has 2 free parameters:
  - Yield of ϒ(1S+2S+3S)
  - Yield of Drell-Yan + $b\bar{b}$

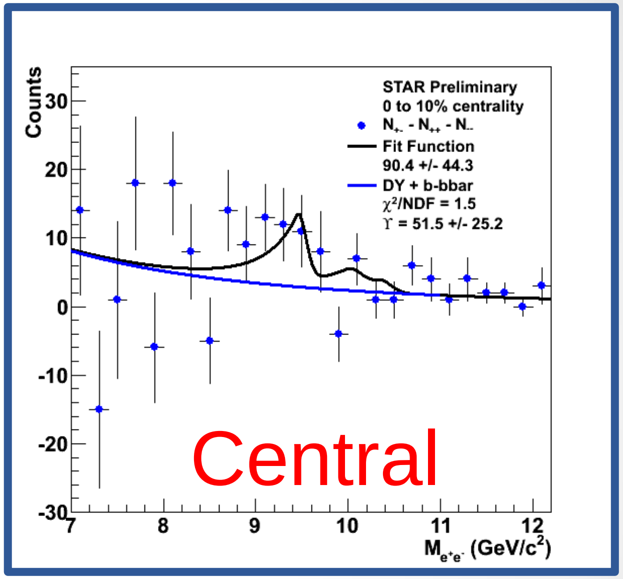


- ϒ yield does **NOT** come from the line shape:
  - $\Upsilon = N_{+-} - N_{--} - N_{++} - \int DY+b\bar{b}$
  - ϒ masses are fixed to PDG Values
  - Ratios of 1S to 2S to 3S fixed to PDG values
  - Other effects come from simulation

ϒ Yield by centrality

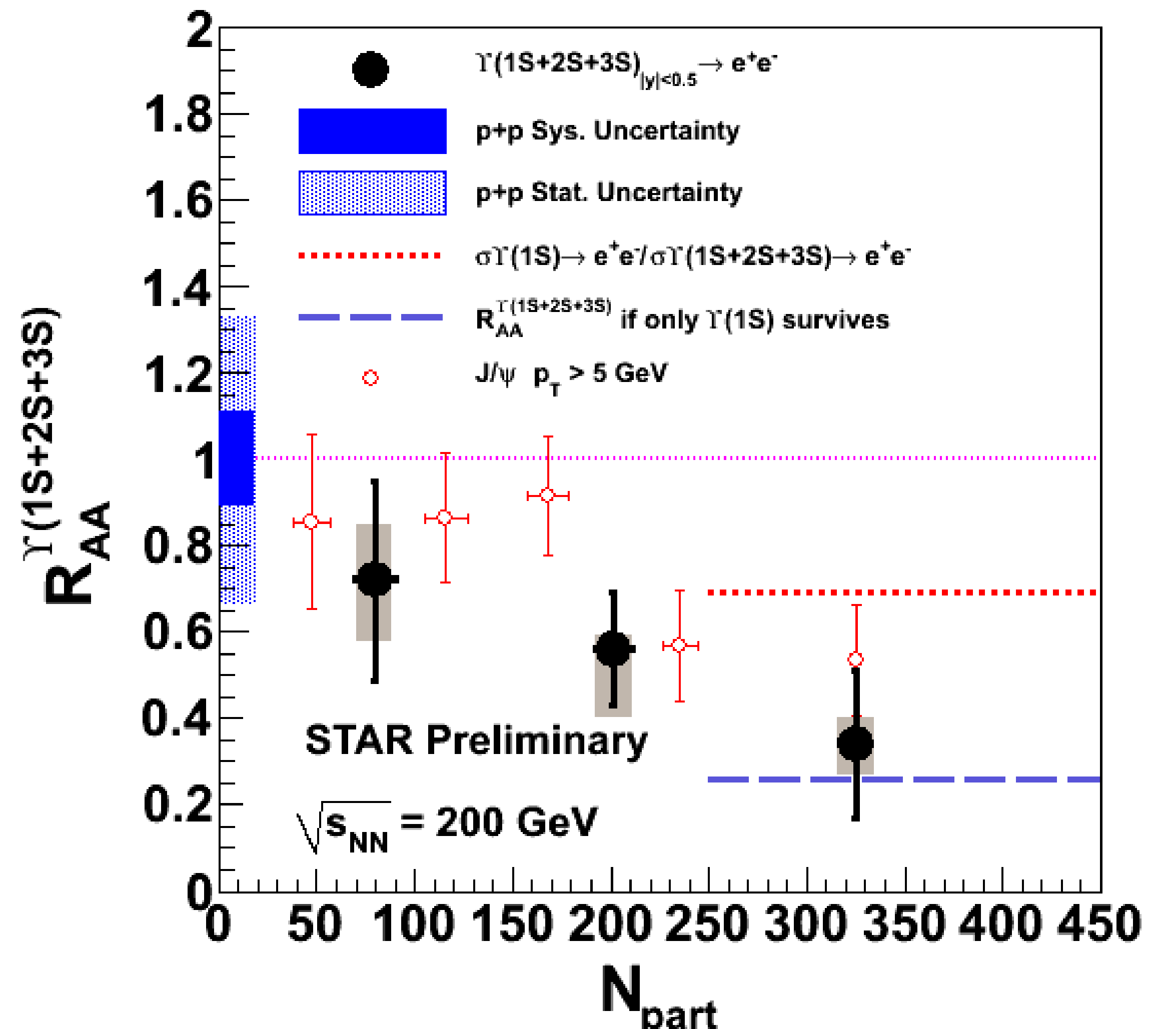




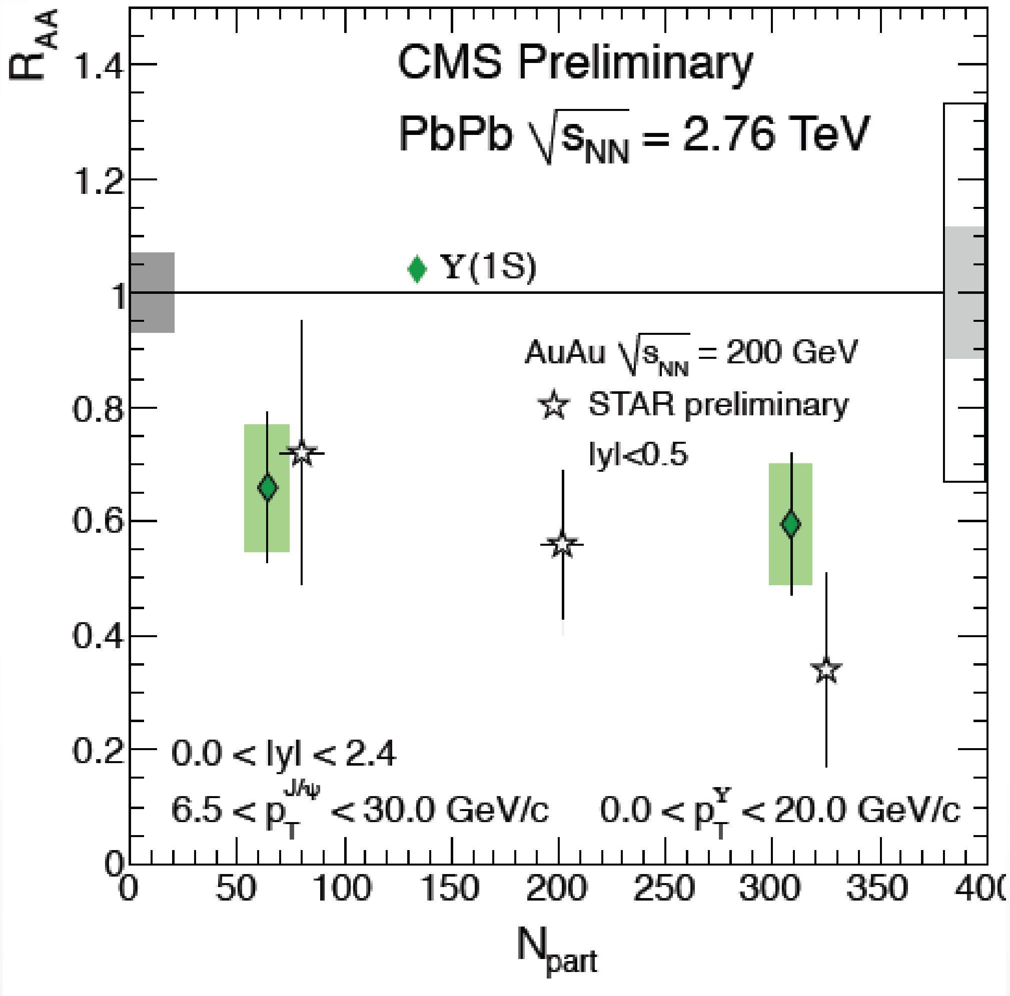


- System uncertainties
  - p+p luminosity and bbc trigger efficiency
  - ϒ Line-shape
  - Drell-Yan and $b\bar{b}$ background

$\Upsilon(1S+2S+3S)\ R_{AA}$



Comparison STAR and CMS



QM2011

Note: STAR data is for the Υ(1S+2S+3S) state and the CMS is for the Υ(1S) only

Results are consistent

What does the Υ R_{AA} tell us about T?

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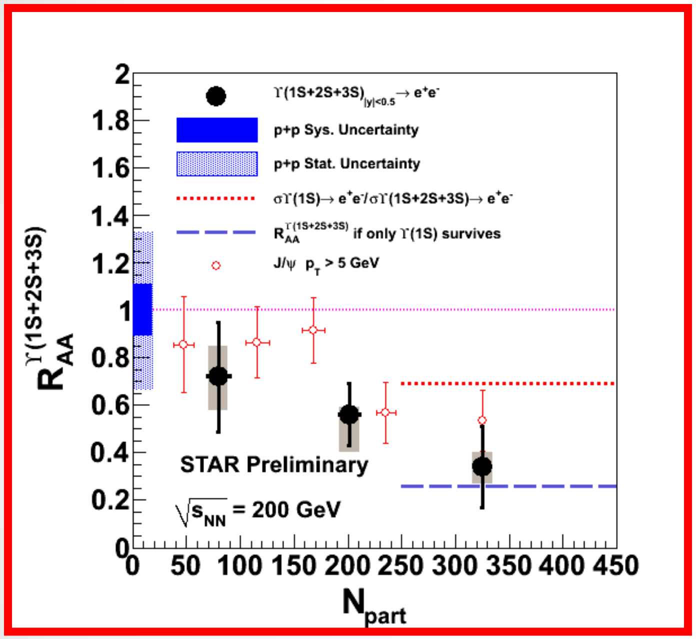

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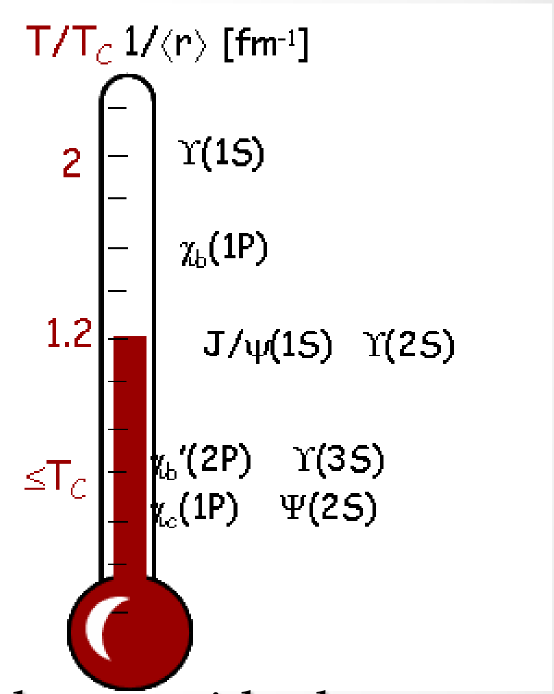

- Now that Υ R_{AA} measurements are available we need to consider how to turn the ratio of states into a temperature
  - Feed-down
  - Core-Corona effects

Conclusions

- Υ(1S+2S+3S) is suppressed in central collisions! 3σ away from $R_{AA} = 1$
- R_{AA} (0-60%)=0.56 ± 0.11(stat)+0.02/-0.14(sys)
- R_{AA} (0-10%)=0.34 ± 0.17(stat)+0.06/-0.07(sys)
  - Additional 33% statistical and 11.4% systematic due to uncertainties on p+p cross-section
- 3x the p+p statistics (run 9) + ~2x the Au+Au statistics (run 11) will decrease the uncertainty